

# PATENT SPECIFICATION

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## COMPLETE SPECIFICATION.

### Turbine Blade Shroud Rings.

We, D. NAPIER & SON LIMITED, a Company registered under the laws of Great Britain, of 211 Acton Vale, London, W.3, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to turbine shroud rings that is to say the shroud rings which closely surround rings of rotor blades in a turbine. It is desirable that the clearance between such a shroud ring and the tips of the rotor blades shall be maintained small and shall not vary to any large degree under different operating conditions, such as the wide temperature variations normally encountered in turbine operation, and it is an object of the present invention to provide a shroud ring construction which will enable the clearance between the shroud ring and the tips of the rotor blades to be maintained within small limits and to prevent or reduce any tendency for the shroud ring as a whole to be distorted under operating conditions.

A turbine according to the present invention comprises a casing and a shroud ring closely surrounding a ring of rotor blades, the shroud ring being in the form of a series of separate arcuate circumferentially-extending sections each connected to the casing by means of a thermal adjusting device including a thermal expansion member so arranged that when the shroud ring and/or the casing or the rotor blades, expand or contract thermally, the radial clearance between the shroud ring and the rotor blades is maintained within small limits of its designed value.

Preferably each thermal adjusting device comprises a low expansion member (that is

a member with a low co-efficient of thermal expansion) connected to the casing and extending radially outwards, and a high expansion member connected to the outer end of the low expansion member and extending radially inwards, and connected at its inner end to a section of the shroud ring.

Thus in one preferred construction the low expansion member is in the form of a sleeve extending radially outwards from the casing while the high expansion member is in the form of a tube or rod lying partly within the sleeve and secured at its outer end to the outer end of the sleeve, and passing through an aperture in the wall of the casing, its inner end being secured to one of the sections of the shroud ring. In any case each of the shroud ring sections is preferably connected to the next adjacent segment in a manner permitting relative movement at the point of connection in a circumferential direction, to compensate for example for thermal expansion, while locating the two adjacent ends of the sections relative to one another in a radial direction.

The connection between adjacent ends of the sections is preferably constructed as described and claimed in co-pending Application No. 36510/54 (Serial No. 785,466).

The invention may be performed in various different ways but one specific embodiment will now be described by way of example with reference to the accompanying drawings, in which:—

Figure 1 is a fragmentary sectional view through part of the turbine showing the periphery of two turbine rotor discs, and the adjacent part of the turbine casing; and

Figure 2 is a fragmentary cross sectional view through the turbine casing and shroud ring on the line II—II in Figure 1.

In this embodiment of the invention the

turbine comprises an outer built-up casing 10, and two rotor discs 11, 12, each carrying a ring of rotor blades 13, 14. Each ring of rotor blades is surrounded by a shroud ring but only one such ring surrounding the rotor blade ring 13 will be described in detail. A ring of stator blades 15 is also supported from the casing 10 in a manner generally known per se so as to lie between the rotor blade rings and the casing also supports a ring of inlet guide vanes 16 upstream of the first rotor blade ring 13.

The shroud ring assembly surrounding the blade ring 13 comprises a supporting structure formed by the adjacent part of the outer tubular casing 10 and a shroud ring comprising a series of separate arcuate sections 17 each of channel-shaped cross section in planes containing the axes of the turbine as shown in Figure 1, with the sides 18, 19 of the channel extending radially outwards from the base 20 of the channel. The base of the inner circumferential wall 20 of each arcuate section, is in the form of a section of a frustum of a cone so that the inner circumferential surface of the shroud ring as a whole is of frusto-conical form to conform to the volume swept by the rotor blade ring 13, with due allowance for a small clearance as shown in exaggerated proportions in Figure 1. The arcuate sections 17 constituting the shroud ring are arranged in a circumferential channel or recess in the casing 10. Each arcuate section of the shroud ring is closed at its ends as shown in Figure 2, the wall 21 closing one end being of substantial thickness and being provided with a screw-threaded bore the axis of which is radial with respect to the tubular outer casing.

Each arcuate section 17 is secured to the tubular outer casing 10 by thermal expansion devices comprising a bolt 25 of high expansion steel (that is to say a material with a high co-efficient of thermal expansion) passing through an aperture in this casing, and with its inner screw-threaded end engaging the screw-threaded bore in the adjacent end wall 21 of the respective arcuate shroud section. The bolt may have a central drilling 26 extending longitudinally from its inner end, which may be exposed on the inner surface of the shroud ring section, so that the whole interior of the bolt is in direct contact with the hot gases passing through the turbine. The outer end of the high expansion bolt 25, which extends an appreciable distance outside the casing, is secured by means of a screw-threaded collar 27 and a cap 28 to a low expansion steel sleeve 29 surrounding the outer end of the bolt, the inner end of this sleeve 29 being rigidly secured to the casing 10. The bolt 25 and the sleeve 29 are a free fit on one another to permit relative movement.

It will be seen therefore that when the thermal adjusting device, in common with the other parts of the turbine, is subject to increased temperatures the high expansion bolts 25 will cause the adjacent end of the respective arcuate shroud sections to move radially inwards relative to the tubular turbine casing 10, so as to compensate for the expansion of the casing. In practice by appropriate design of the parts, and selection of appropriate materials and lengths for the high and low expansion members, the clearance between the shroud ring sections and the tips of the rotor blades may be maintained within very close limits over the whole operating range of temperatures. The co-efficient of thermal expansion of the bolts 25 in one preferred example is approximately  $22.7 \times 10^{-6}$  per °C. while that of the sleeves 29 is approximately  $4.8 \times 10^{-6}$  per °C.

Each end of each arcuate section 17 is moreover provided with a step lying in a tangential plane, the face of the step 30 on the fixed end 21 of each arcuate section facing radially outwards while the face of the step 31 on the opposite free end of each arcuate section faces radially inwards. The steps on the adjacent ends of the arcuate section engage one another so that the free ends of the arcuate sections can move circumferentially to a limited extent relatively to the fixed ends of the sections which they engage but are held from inward radial movement. The clearance is shown much exaggerated for clarity in Figure 2.

Alternatively, in place of the step formation described, each end of the arcuate shroud sections may be provided with a slot running in a tangential plane, each pair of adjacent slots co-operating with a key which acts to restrain the adjacent ends of the sections from relative movement in a radial direction, but allows them to move relative to one another in a circumferential direction. In any case it will be seen that this construction enables each arcuate shroud section to be located radially from the tubular turbine casing, through the thermal adjusting devices, and automatically absorbs any circumferential expansion in the individual sections.

Mounted within each arcuate section 17 is a sheet metal baffle 32 provided with local projections to locate it within the arcuate section while providing between the baffle and the walls of the arcuate section a narrow passage 34 through which cooling air can be caused to flow. The arrangement is conveniently such that one side of the baffle, for example that at the upstream side of the arcuate section is open to a cooling air inlet passage leading from a cooling air chamber 33 in the tubular outer casing so that cooling air is caused to flow through this narrow cooling air passage 34 before escaping, for

example through an outlet opening 35 in the base of the arcuate section, into the main gas stream passing through the turbine.

#### WHAT WE CLAIM IS:—

1. A turbine comprising a casing, and a shroud ring closely surrounding a ring of rotor blades, the shroud ring being in the form of a series of separate arcuate circumferentially-extending sections each connected to the casing by means of a thermal adjusting device including a thermal expansion member so arranged that when the shroud ring and/or the casing or the rotor blades expand or contract thermally, the radial clearance between the shroud ring and the rotor blades is maintained within small limits at its designed value.

2. A turbine as claimed in Claim 1 in which each thermal adjusting device comprises a low expansion member (that is a member with a low co-efficient of thermal expansion) connected at one end to the casing and at its other end to one end of a high expansion member, the opposite end of the high expansion member being connected to a section of the shroud ring.

3. A turbine as claimed in Claim 2 in which the low expansion member is in the

form of a sleeve extending radially outwards from the casing while the high expansion member is in the form of a tube or rod lying partly within the sleeve and secured at its outer end to the outer end of the sleeve, and passing through an aperture in the wall of the casing, its inner end being secured to one of the sections of the shroud ring.

4. A turbine as claimed in any of the preceding claims in which each of the shroud ring sections is connected to the next adjacent section in a manner permitting relative movement at the point of connection in a circumferential direction, to compensate for example for thermal expansion, while locating the two adjacent ends of the sections relative to one another in a radial direction.

5. A turbine as claimed in Claim 4 in which the connection between adjacent ends of the sections is as claimed in any of the claims of co-pending Application No. 36510 of 1954 (Serial No. 785,466).

6. A turbine including a shroud ring substantially as described with reference to the accompanying drawings.

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Agents for the Applicants.

#### PROVISIONAL SPECIFICATION.

##### Turbine Blade Shroud Rings.

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This invention relates to turbine shroud rings that is to say the shroud rings which closely surround rings of rotor blades in a turbine. It is desirable that the clearance between such a shroud ring and the tips of the rotor blades shall be maintained small and shall not vary to any large degree under different operating conditions, such as the wide temperature variations normally encountered in turbine operation, and it is an object of the present invention to provide a shroud ring construction which will tend to enable the clearance between the shroud ring and the tips of the rotor blades to be maintained within small limits and to prevent or reduce any tendency for the shroud ring as a whole to be distorted under operating conditions.

A turbine according to the present invention comprises a casing and a shroud ring closely surrounding a ring of rotor blades, the shroud ring being in the form of a series of separate arcuate circumferentially extending sections each connected to

the casing by means of a thermal adjusting device including a thermal expansion member so arranged that when the shroud ring and/or the casing or the rotor blades, expand or contract thermally, the radial clearance between the shroud ring and the rotor blades is maintained within small limits at its designed value.

Preferably each thermal adjusting device comprises a low expansion member (that is a member with a low co-efficient of thermal expansion) connected to the casing and extending radially outwards, and a high expansion member connected to the outer end of the low expansion member and extending radially inwards, and connected at its inner end to a section of the shroud ring.

Thus in one preferred construction the low expansion member is in the form of a sleeve extending radially outwards from the casing while the high expansion member is in the form of a tube or rod lying partly within the sleeve and secured at its outer end to the outer end of the sleeve, and passing through an aperture in the wall of the casing, its inner end being secured to one of the sections of the shroud ring. In any case each of the shroud ring sections is preferably connected to the next adjacent seg-

ment in a manner permitting relative movement at the point of connection in a circumferential direction, to compensate for example for thermal expansion, while locating the two adjacent ends of the sections relative to one another in a radial direction.

The connection between adjacent ends of the sections is preferably constructed as described and claimed in co-pending Application No. 36510/54 (Serial No. 785,466).

The invention may be performed in various different ways but one specific embodiment will now be described by way of example.

In this embodiment of the invention a three stage turbine comprises a cylindrical outer casing on which is mounted three shroud ring assemblies associated with the three rotor blade rings. Two rings of stator blades are also supported from the casing in a manner generally known per se so as to lie between the rotor blade rings.

Disposed immediately in advance of the first ring of stator blades, that is to say around the ring of rotor blades constituting the first stage, is a shroud ring assembly comprising a supporting structure formed by the appropriate part of the outer tubular casing and a shroud ring comprising a series of separate arcuate sections each of channel shaped cross section in planes containing the axes of the turbine with the sides of the channel extending radially outwards from the base of the channel. The inner circumferential wall of each arcuate section, is in the form of a section of a frustum of a cone so that the inner circumferential surface of the shroud ring as a whole is of frusto-conical form to conform to the shape of the rotor blades. The arcuate sections constituting the shroud ring are arranged in a circumferential channel or recess, one side of which is formed by an annular step on the inside of the tubular outer casing while the other side is formed by a separate plate secured to the casing and projecting radially inwardly therefrom. The channel section element constituting each arcuate section of the shroud ring is closed at its ends, the wall closing one end being of substantial thickness and being provided with a screw-threaded bore the axis of which is radial with respect to the tubular outer casing.

Each arcuate section is secured to the tubular outer casing by thermal expansion devices comprises a bolt of high expansion steel (that is to say a material with a high co-efficient of thermal expansion) passing through an aperture in this casing, and with its screw-threaded end engaging the screw-threaded bore in the adjacent end of the arcuate shroud section. The bolt may have a central drilling extending longitudinally from its inner end, which may be exposed on the inner surface of the shroud ring

section, so that the bolt is in direct contact with the hot gases passing through the turbine. The outer end of the high expansion bolt, which extends an appreciable distance outside the casing, is secured by means of a screw-threaded collar to a low expansion steel sleeve surrounding the outer end of the bolt, the inner end of this sleeve being rigidly secured to the casing. The bolt and the sleeve are a free fit on one another to permit relative movement. It will be seen therefore that when the thermal adjusting device, in common with the other parts of the turbine, is subject to increased temperatures the high expansion bolt will cause the adjacent end of the arcuate shroud section to move radially inwards relative to the tubular turbine casing, so as to compensate for the expansion of the casing. In practice by appropriate design of the parts, and selection of appropriate lengths for the high and low expansion members, the clearance between the shroud ring sections and the tips of the rotor blades may be maintained within very close limits over the whole operating range of temperatures.

Each end of each arcuate section is moreover provided with a step lying in a tangential plane, the face of the step on the fixed end of each arcuate section facing radially outwards while the face of the step on the free end of each arcuate section faces radially inwards. The steps on the adjacent ends of the arcuate section engage one another so that the free ends of the arcuate sections can move longitudinally to a limited extent relatively to the fixed ends of the sections which they engage but are held from inward radial movement.

Alternatively, in place of the step formation described, each end of the arcuate shroud sections may be provided with a slot running in a tangential plane, each pair of adjacent slots co-operating with a key which acts to restrain the adjacent ends of the sections from relative movement in a radial direction, but allows them to move relative to one another in a circumferential direction.

In any case it will be seen that this construction enables each arcuate shroud section to be located radially from the tubular turbine casing, through the thermal adjusting devices, and automatically absorbs any circumferential expansion in the individual sections.

Mounted within each arcuate section is a sheet metal baffle provided with local projections to locate it within the arcuate section while providing between the baffle and the walls of the arcuate section a narrow passage through which cooling air can be caused to flow. The arrangement is conveniently such that one side of the baffle, for example that at the downstream side of the arcuate section is open and a cooling

air inlet passage leading from a cooling air chamber in the tubular outer casing communicates through this open side with the interior of the baffle while a cooling air exit  
5 passage communicates with an appropriate point in the narrow cooling air passage referred to so that cooling air delivered through the cooling air inlet passage is caused to flow through this narrow cooling  
10 air passage before escaping from the cooling air passage, for example through an outlet opening situated in the downstream side of the arcuate section where it will deliver the cooling air into the main gas stream passing  
15 through the turbine.

The shroud ring assembly associated with the second turbine stage may be of generally

similar construction to that described above with reference to the first turbine stage apart from dimensional changes, the arrangement  
20 of the baffle and of the cooling air inlet and exit passages in each section of the shroud ring however being such that cooling air will be delivered from the cooling air chamber referred to above and be directed  
25 by the baffle through a narrow channel between the baffle and the walls of the arcuate section before passing into the gas stream. Thus the cooling air flows from the cooling  
30 air chamber in opposite directions into the sections of the two shroud rings.

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COMPLETE SPECIFICATION

I SHEET

This drawing is a reproduction of  
the Original on a reduced scale.

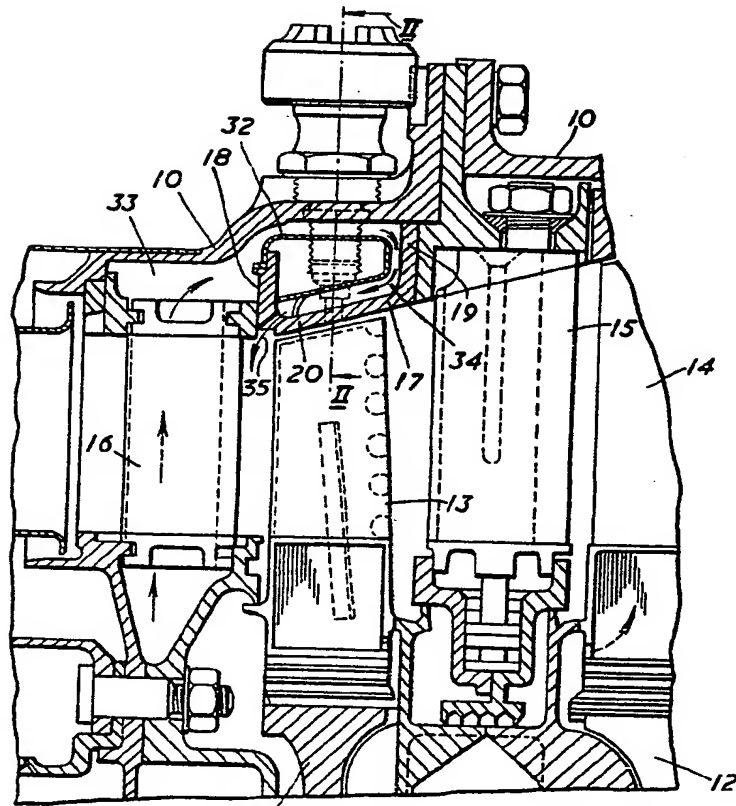


FIG. 1.

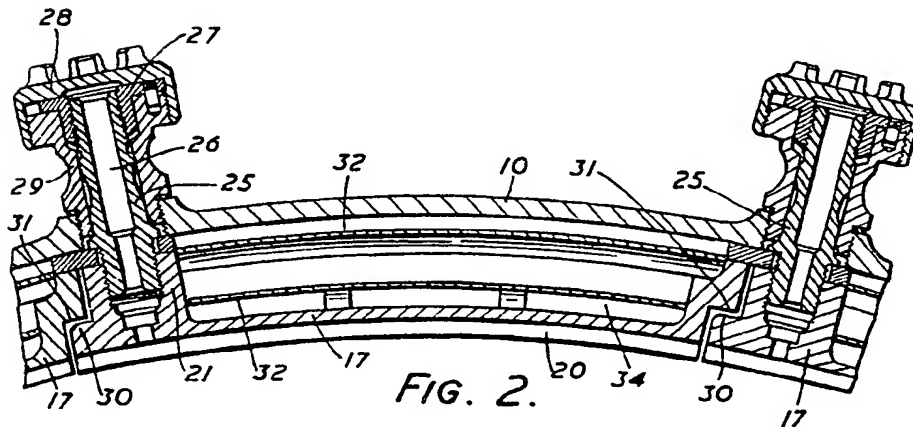


FIG. 2.